Absorption Properties of NASA Flight Approved Materials and other Testable Samples

Matthew Sisson and Justin Mann

Faculty Mentor: Dr. William V. Slaton

University of Central Arkansas, Department of Physics and Astronomy

Abstract

The purpose of this project is to analyze the acoustic impedance and absorption properties of various flight approved materials currently and potentially used by NASA in its work with the International Space Station. These materials, consisting of Bisco, Acoustifoam, and other metallic foams, in addition to Durette, Kevlar, and other manufactured felts, will be used in an experimental procedure utilizing an impedance tube. By using the results of the experiment as a means to measure sound absorption coefficients of specific materials, these tested, flight approved materials, and other testable materials, may be specifically arranged and utilized to both maximize efficiency and minimize excess noise. These possible applications will not only provide scientific data but also potentially affect astronauts on current and future missions for NASA.

Theory

The testing method uses an impedance tube with a sound source connected to one end and a test sample mounted at the other. Plane waves are generated within the tube by the use of a signal analyzer connected to the sound driver. The wave pattern is decomposed into forward and backward traveling components by simultaneously measuring sound pressures at two fixed locations in the tube's wall.

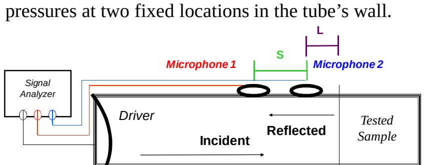


Figure 1: Impedance Tube Representation

Calculating the absorption coefficients under normal incidence is done by analyzing series of complex data from the transfer function between the two microphones. Finding the transfer function of the two microphones corrected for response mismatch, denoted as **H**, and the phase of the complex transfer function, denoted as φ, allows for evaluating the complex acoustic reflection coefficient **R** as,

$$|R|^2 = \left[\frac{1+|H|^2-2|H|\cos(\varphi+ks)}{1+|H|^2-2|H|\cos(\varphi-ks)}\right] \quad \text{where} \quad k=\frac{2\pi f}{c}$$

and with f and c denoting frequency and speed of sound respectively. The absorption coefficient α, the focus of this project, is directly related to the reflection coefficient R and can be calculated as,

$$\alpha = 1-|R|^2.$$

Experimental Setup

In order to use the two Larson Davis microphones we received, we had to develop a power supply. We wished to generate the transfer function from the raw readings of the two high quality microphones while following the ASTM International (Designation E1050-08) "Standard Test Method for Impedance and Absorption of Acoustical Materials Using A Tube, Two Microphones and A Digital Frequency Analysis System." The 5-pin microphones were powered by two power supply boxes, one consisting of a transformer, a Symmetric 1A Power Supply Kit, and a cooling fan. These two boxes were wired together and connected to a 200-volt Laboratory Power Supply and the signal analyzer in channels corresponding to the microphone number.

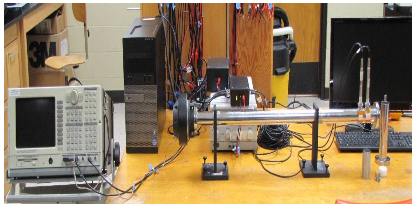


Figure 2: Experimental Setup consisting of a signal analyzer, impedance tube, and power supplies

Testing Procedure

Each day of testing began with calibration. A calibration foam was mounted as the tested sample in two tests, the first in the standard configuration as depicted before in Figure 1 and the second in a configuration with the microphones in switched positions, allowing for microphone mismatches to be corrected. Once calibrated, the impedance tube was placed back into standard configuration in testing the various foam samples. Each test recorded the frequency response measurement between the two microphones in 2000 data points as the driver swept frequencies 200Hz to 5kHz with a 1-volt sound source. Through the use of SR785 Data Viewer and Microsoft Excel, each frequency dependent quantity was calculated in order to graph the absorption coefficients of each tested material. In total, over 30 different materials were tested. These included a collection of materials sent from Johnson Space Center and various samples selected in the University of Central Arkansas Laboratory.

Figure 3: Melamine Test Comparison

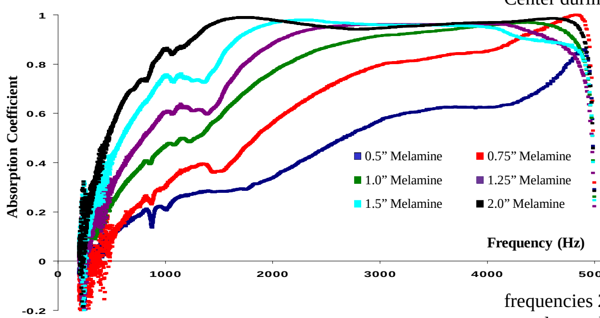
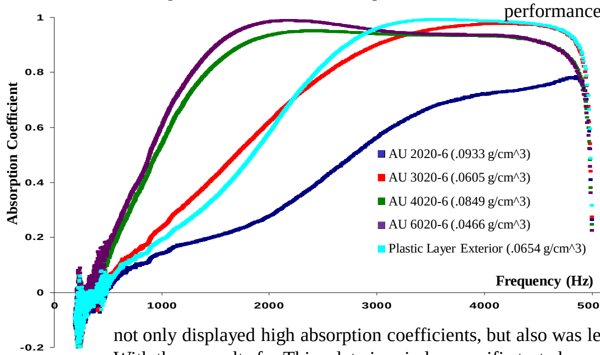


Figure 4: Thinsulate Test Comparison



Absorption Results

Our data series began with various graphs investigating Melamine. Our data for this material was compared to data provided by Johnson Space Center during the start of our experimentation. Once our testing procedure was validated, we began comparing the absorption coefficient values among specific combinations of Melamine samples. In Figure 3, we saw the relationship between sound absorbance and thickness of the tested materials. While the overall values of the absorption coefficients began to increase with thicker Melamine samples, the values began to converge between frequencies 2.5 kHz-5kHz. Because of this, smaller samples could be selected in order to meet the needs of manned space vehicles based upon their performance as being similar to a sample with twice the thickness. Another material of interest was Thinsulate. We received a collection of five Thinsulate materials, each with a specific composition, and plotted the absorption coefficients as illustrated in Figure 4. In testing these materials we began to investigate a possible relationship between a tested sample's absorptive properties and its physical makeup. For Thinsulate in particular, the AU 6020-6 sample not only displayed high absorption coefficients, but also was less dense than the other five samples. With these results for Thinsulate in mind, a specific tested sample can be evaluated by both its acoustic properties and physical density, creating a need to both maximize acoustic performance and minimize the cost of incorporating various materials into manned space vehicles.

Future Goals

While calculating absorption coefficients over a range of frequencies has been successful, we also wish to view the absorptive behavior over specific frequency bands. Materials can be then be evaluated based upon their density and sound absorbance to fit the needs of manned space vehicles. The standard provides equations for evaluating the real and imaginary parts of the impedance. While the real and imaginary parts of impedance have been calculated for some materials, the values are including the impedance properties of the piston back plate. To minimize this, we are planning to develop the mathematical model to include an air gap between the test samples and back plate.

Figure 5: Collection of Melamine and Thinsulate samples

Acknowledgements

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